DISEASES OF

CABBAGE

and related plants

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CABBAGE DISEASES are preventable in the main by simple means of plant sanitation.

Rotation of crops should be practiced. Crops that belong to the cabbage family, such as cauliflower, turnip, brussels sprouts, and kale, should be avoided in the rotation. Keep down mustard and related weeds, which harbor cabbage pests.

Drainage water, refuse from diseased cabbage fields, and stable manure with which diseased material has been mingled will carry infection.

The seedbed is often the source of infection. The greatest pains should be taken to insure healthy plants. Locate the seedbed on new ground if possible, or sterilize by steam the soil used.

Soil infested with the clubroot organism should be avoided. Cabbage seed should be disinfected before planting, to prevent black rot and blackleg. Yellows is due to a fungus which persists in the soil for many years. Varieties of cabbage resistant to this disease are available.

This bulletin is a revision of Farmers' Bulletins 925 and 1351, Cabbage Diseases, which it supersedes.

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DISEASES OF CABBAGE AND RELATED PLANTS

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CABBAGE AND OTHER CRUCIFERS

FROM THE ORIGINAL wild stocks of the cabbage group have come cultivated cabbage, cauliflower, broccoli, brussels sprouts, kohlrabi, collards, and kale. Other cultivated plants closely related to these are turnip, radish, rape, rutabaga, and horseradish. Among the related wild plants shepherds-purse, peppergrass, and mustard are of most frequent occurrence. Mustard is sometimes cultivated, but some species grow so profusely under all conditions that they are more commonly classed as weeds. The term "crucifers" as used in this bulletin refers collectively to all the vegetables and weeds mentioned in this paragraph, all of which belong to the botanical family Cruciferae, so-called from the form of the four-petaled flower. Many of them are subject to the same diseases, so that the methods of control of the diseases of cabbage and its close relatives can often be applied to other crucifers as well.

PARASITIC AND NONPARASITIC DISEASES

A large number of the diseases discussed in this bulletin are brought about by the attack of the plant by microscopic organisms—bacteria and fungi—or ultramicroscopic agencies known as viruses. This class of diseases collectively is referred to here as parasitic diseases.

Their development is influenced greatly by the climate and by the condition of the soil, as these environmental factors affect not only the aggressiveness of the parasite but also the susceptibility of the plant it attacks.

There are many disease conditions in which no parasite is involved. They result from the detrimental influence of certain climatic and soil conditions upon the crop. This group is referred to as nonparasitic diseases. Outstanding examples of nonparasitic diseases of cabbage are soil-mineral-deficiency injuries (for example, potash starvation), flooding injury, and freezing injury.

PARASITIC DISEASES AND THEIR CONTROL

GENERAL CONTROL PRACTICES

Use of Disease-Free Seed

Blackleg and black rot are more or less prevalent in all the cabbage sections in the Central, Eastern, and Southern States. The germs of both maladies readily overwinter on even mildly infected seed heads, and they then attack the seed plants the following season. From a diseased field it is almost impossible to select seed heads that are positively free from these diseases. The most effective means of ridding seed stock of them, therefore, is to start with clean or thoroughly disinfected seed. By planting clean seed in a clean seedbed and in a clean field, these troublesome diseases may be avoided and clean seed produced.

American cabbage growers, as a rule, prefer to buy seed rather than to grow their own. In general this custom is based on sound economic principles and is likely to continue. Seed growing is an industry in itself and requires specialized cultural methods and certain favorable climatic conditions. Because of these facts most of the American supply of cabbage seed is grown in Pacific coast sections, which usually appear to be practically free from blackleg and black rot. A study of climatic conditions as affecting these diseases leads to the belief that the dry season in midsummer serves to discourage their development in those sections. American-grown cauliflower seed is produced chiefly in the coastal valleys of California, where such seed crops have so far been found to be free from blackleg and black rot.

If the grower is certain his cabbage seed has been grown in Pacific coast sections, it has been considered reasonably safe to plant it without treatment; but recently the blackleg organism has been found on some lots of seed from those western sections. It is safest, therefore, to use the hot-water seed treatment for all members of the cabbage group (p. 1), turnip, rutabaga, and rape. Semesan may be applied as a dust following hot-water treatment, but it is not a substitute for the latter, since it serves only to protect seed and young seedlings from damping-off fungi in the soil. Dusts containing copper are injurious to crucifer seed.

See warning about the handling of mercury compounds (p. 22).

Hot-Water Seed Treatment

Hot-water seed treatment must be applied with great care, since it is likely to reduce germination somewhat. Old seed is more likely to suffer in this respect, and in some cases the length of treatment

must be reduced because of this fact. It is well, therefore, to run a preliminary test on a few hundred seeds, followed by a germination test, before treating an entire lot. The seed is placed loosely in a cheesecloth sack. It is then immersed in water held at 122° F. for 15 to 30 minutes, depending upon how long the particular lot will stand being immersed without the rate of germination being greatly reduced. It is essential to keep the water continuously agitated and to maintain the temperature by the frequent addition of hot water without applying it directly to the seed. At the end of the treatment, immerse the seed in cold water, drain, and spread in a thin layer to dry.

Seedbed Sanitation

Cabbage, cauliflower, and certain other cruciferous crops are generally started in a seedbed. As previously pointed out, the causal organisms of some of the most destructive diseases may be transferred to noninfested fields by plants from the seedbed. The mistake is often made of placing the bed on an old cabbage field on which diseases have been present, or often manure is taken from the heap on which diseased plants have been thrown to compost or from animals that have fed on diseased root crops. In either case there is great danger of having an infested seedbed, and the transfer of diseased plants to the field naturally means the transfer of the disease germs affecting them. Kale, rape, and collards are commonly affected with black rot, especially in the South; soil on which they are growing or on which they have grown during the previous 3-year period should be avoided for the seedbed. When it is necessary to use old soil that may contain the germs that cause crucifer diseases, this soil should be disinfected with live steam, as described in Farmers' Bulletin 1629, Steam Sterilization of Soil for Tobacco and Other Crops.

Care in Purchase of Plants

It is obvious from what has just been said concerning care of the seedbed that extreme caution should be taken in the purchase of plants. It is not always possible to detect diseases at the time of transplanting, even though they are present in incipient form. The only safe procedure, therefore, is to make sure that proper seed was used and that seedbed sanitation was practiced in growing the plants to be purchased.

Crop Rotation

Because the germs that cause certain diseases overwinter in soil and refuse, repeated cropping of the soil with the same kind of plant or related ones favors the multiplication of disease organisms. The lack of data as to just how long is needed to starve out a given organism, as well as regional variations in climate and soil, makes definite recommendation as to length of rotation difficult. Blackleg and black rot organisms overwinter in the soil in the North to some extent, but a 2- to 3-year rotation of the transplant field seems to be satisfactory. When the causal organism of yellows is once established, however, it is so persistent that its reduction by means of rotation is out of the question. The clubroot organism is also very persistent in the soil. Even long rotation and complete eradication of related wild plants that may harbor the organism are not sure means of ridding the soil of the parasite.

Known in Europe for several centuries, clubroot is now world-wide in its occurrence. It probably causes the greatest losses to turnip and rutabaga where these crops are grown extensively for stock feed—as in northern Europe and in New Zealand. In vegetable gardens and in truck-crop districts the disease is very common on cabbage, cauliflower, broccoli, brussels sprouts, kohlrabi, and Chinese cabbage, as well as on radish, turnip, and rutabaga. Inasmuch as the causal organism infects many species of crucifers, wild plants and weeds of that family (such as mustard), as well as cultivated ornamentals (such as wallflower and stock), are affected. The losses due to clubroot are sometimes very heavy, and the economic importance of the disease is increased by the fact that soil once infested commonly remains so for an indefinite period even in the absence of susceptible host plants.

Characteristics

The outstanding symptom of clubroot is the abnormal enlargement of the roots (fig. 1, *B*). These enlargements may occur on the very small roots, the secondary roots, the taproot, or the underground part of the stem. The root clubs are often thickest at the center, tapering spindlelike toward either end. The normal processes of the roots are of course disturbed by this malformation. Clubbed roots commonly decay before the end of the season because they are not adequately protected from secondary soil organisms.

In plants in which fleshy roots are normally formed—turnip, rutabaga, and radish—infection is commonest on the secondary roots. On the fleshy roots it occurs chiefly where the side roots emerge. Therefore, in fleshy-rooted species differences in reaction to clubroot correspond to the forms of the roots. In globe varieties secondary roots arise chiefly from the nonfleshy taproot and the edible roots are not commonly infected by the clubroot organism, whereas in the long and half-long varieties, in which the secondary-root zones extend approximately half the length of the fleshy root, the fleshy root is commonly invaded by the clubroot organism and deformed by club formation.

The eventual effect of the root disturbance is to stunt the plant. This stunting does not always occur promptly, however. A seedbed, for instance, may show no evidence of disease in the above-ground parts of the plants, but when the plants are pulled they may be found to have fair-sized root clubs. Likewise, infection occurring in the field may easily escape notice because the stunting of the plants is often very slow. Mildly affected cabbage or cauliflower plants may form fair-sized heads. If the environmental conditions favor rapid development of the disease, however, the stunting may be sudden and pronounced and the plants may wilt during the middle of bright days (fig. 1, *A*). Permanent wilting may accompany advanced decay of the enlarged roots.

Causal Organism

The parasite associated with clubroot is a minute organism (*Plasmodiophora brassicae* Wor.), the spores of which remain in the soil

Figure 1.—Two phases of clubroot on cabbage: *A,* Wilting of half-grown plants that have severely clubbed roots; *B,* malformed spindlelike roots.

for long periods. With favorable temperature and moisture, some of the spores germinate and each gives rise to a small motile body which penetrates the underground parts of the host plant. Once within the host, it enlarges, probably divides, and progresses slowly through the tissues. The presence of the parasite stimulates abnormal growth of the affected parts, but the normal development of the water- and food-conducting vessels is inhibited. The clubbed roots therefore do not function properly, and their abnormal growth draws the sugar made in the leaves and diverts it from its normal storage place, such as the cabbage head. Later the clubroot organism divides into innumerable individual spores which are so constituted as to be able to withstand long periods of unfavorable weather. They are returned to the soil when the cabbage roots rot.

Conditions Favoring Clubroot

Even though a susceptible cruciferous plant is growing upon soil infested with the clubroot organism, it does not necessarily follow that the plant becomes diseased. The surrounding conditions must be such that host and parasite react together to develop the disease. Clubroot develops over nearly as wide a range of temperature as that at which the host will ordinarily grow; thus the disease is not restricted to any region on this account. In very dry soil the spores of the parasite fail to germinate, and it is possible to prevent infection by keeping the soil moisture constantly at a low level. However, this is of little practical value, since a rise in soil moisture for as short a time as 18 hours is sufficient to permit spore germination and infection; after that period a return to low soil moisture does not prevent club formation.

Acidity or alkalinity of the soil has a great effect on clubroot. The clubroot organism is sensitive to an alkaline condition. If infectious soil is made alkaline (pH [1] 7.2 or above) and kept uniformly moist, little or no infection occurs and the plants grow normally and remain healthy. This fact is the basis of the long-known beneficial effects of lime as a specific remedy for clubroot. However, the application of lime sufficient to increase the soil pH to 7.2 or higher does not always lead to disease control. This is explained by the fact that, although the bulk of the soil moisture is alkaline, the soil-moisture film immediately around the rootlets may be acid, because carbon dioxide is continually being given off by the rootlets. It appears that in moist soil there is sufficient movement of alkaline particles to neutralize the acid promptly, while in drier soil this may not hold. Thus in the latter instance the favorable condition for germination of spores of the clubroot organism prevails in that most important region, that immediately around the roots.

The facts just mentioned are extremely important in the control of the disease. They explain why liming is sometimes successful and sometimes not. The effectiveness of this remedial measure varies with the soil type, the season, and the locality, depending upon how completely the external environment permits the protection of the root system from the clubroot parasite.

[1] The "pH value" is the most common term used to express the degree of acidity or alkalinity. A neutral soil has a pH value of 7; values above 7 denote alkalinity and those below 7 acidity.

It has been pointed out that soil contaminated with the clubroot organism usually remains infectious for many years. Crop-rotation systems wherein long intervals between cruciferous crops prevail are not very effective in reducing soil infestation. If possible, it is better to abandon badly infested soil for crucifers for an indefinite period.

The clubroot organism is not carried with the seed. It is carried readily, however, with infested soil, crop refuse, and infected plants from locality to locality and from field to field. Badly infested areas having been abandoned, it is important to prevent the contamination of clean fields. Infested soil is carried readily on farming implements, by man and animals, by surface floodwaters, by transplants from infested beds, and by any propagative plant parts such as potato seed tubers and bulbs. Manure from stock fed on diseased root crops is infectious. By these various means the clubroot organism is continually being transported, and such transfers must be checked in order to prevent spread of this disease.

The benefits and limitations of liming have already been discussed. Where crucifers are a dominant crop an alkaline soil is desirable. When favorable soil-moisture levels prevail, reduction of clubroot may be expected; furthermore, new contamination of such soils is less likely to occur. It should be borne in mind, however, that neutral or slightly alkaline soils are particularly favorable to common scab of potato. In areas where high acidity of the soil is essential for scab control, obviously it will not be possible to bring about clubroot control through adjustment of soil reaction.

The use of resistant varieties to control clubroot has limited possibilities at present. No varieties of cabbage, cauliflower, broccoli, kohlrabi, brussels sprouts, or collards that show any practically important resistance to this disease are known. Garden kales are very susceptible, but some varieties of stock kale are highly resistant. For many years plant breeders in northern Europe have sought to develop rutabagas and turnips that are resistant to clubroot. The Danish Bangholm variety of rutabaga is reported to be resistant in Denmark and Great Britain, and the Bruce turnip is resistant in Scotland and New Zealand. However, neither of these is satisfactorily resistant on very infectious soil in Sweden; a highly resistant turnip, Immuna, has recently been developed there.

The fact that certain varieties of turnip and rutabaga are resistant in some localities indicates that different strains of the clubroot organism occur in different localities. Apparently most of the rutabaga varieties grown in the United States are highly resistant to the parasite as it occurs here; many varieties of turnip are also resistant. Shogoin, an introduced Japanese variety of turnip, is very susceptible in this country, however, and should be avoided where soil is known to be infested.

The important measures for control of clubroot may be summarized as follows:

(1) Discontinue the growing of cruciferous crops on badly infested areas if possible.

(2) Avoid infestation of new areas by selecting clean soil for plant beds; avoid transfer of infectious material from infested areas by implements, farm animals, plants, and surface drainage water.

(3) If compatible with the well-being of other crops in the rotation, keep the soil alkaline.

(4) Use resistant varieties of turnip and rutabaga.

ROOT KNOT

Characteristics

Root knot is most common on crops grown on the light sandy soils in the South; in the Northern States it occurs chiefly in greenhouses. It affects a large number of crop plants and weeds. Although the most distinctive symptoms are root malformations (fig. 2), the indirect effect is a stunted, sickly appearance of the above-ground parts of the host plant.

Figure 2.—Root knot of cabbage.

In an attempt to distinguish root knot and clubroot some confusion is likely to result. Although the organisms associated with the two diseases are quite different, the effects produced on the roots bear some points of resemblance. (Compare figs. 1, *B*, and 2.) Root knot is generally characterized by smaller swellings than clubroot, and infection as a rule is more uniformly distributed on the lateral feeding roots. If, when the swellings on the roots are broken open, pearly-white bodies about the size of a pinhead are found, root knot is to be suspected. These white specks within the swellings are the enlarged egg-bearing female nematodes, or eelworms (*Heterodera*), that indicate the disease. The interior mass of clubroot is slightly pinkish or brick-colored.

Control

Crop rotation has been found to be the most practicable means of controlling root knot. The aim is to use crops immune from or resistant to the disease in order to starve out the eelworms. When this method is employed, a rotation of at least 3 years, accompanied by clean cultivation to keep down weeds, should be practiced.

More than 500 different species of plants already are known to be susceptible to root knot; among these are many cultivated plants and numerous weeds.

The following list of the more important immune or highly resistant crops will be of assistance in planning rotations for the reduction of the trouble:

- Barley
- Beggarweed, Florida
- Chufa
- Corn
- Cowpea:
  - Brabham
  - Iron
  - Monetta
  - Victor
- Crabgrass
- Grass, Bermuda
- Grasses (nearly all)
- Kafir
- Millets (nearly all)
- Milo
- Oats, winter
- Peanut
- Rye
- Sorghum
- Soybean (Laredo variety only)
- Velvetbean
- Wheat

If nematodes occur in the seedbed or in the greenhouse, the soil should be sterilized with live steam.

YELLOWS

The disease called yellows is confined to members of the cabbage tribe (cabbage, cauliflower, broccoli, brussels sprouts, kohlrabi, kale, and collards). It is especially destructive to cabbage and constitutes a serious menace to this crop from Long Island to Colorado, including the southern parts of New York, Michigan, Wisconsin, and Minnesota, and southward as far as cabbage is grown as a summer crop. It is most prevalent in warm weather and does little or no damage in the extreme northern sections or along the northern Pacific coast. It is less severe on winter-grown cabbage in the Southern States. In the latitude of New Jersey and Maryland westward through Ohio, Indiana, Illinois, southern Wisconsin, and Iowa, yellows remained the greatest hazard to cabbage growing until resistant varieties were developed. In thoroughly infested soils it is not uncommon for complete destruction of susceptible varieties to occur.

Characteristics

Plants infected with yellows usually show the characteristic symptoms 2 to 4 weeks after being transplanted, but the disease may appear in the seedbed. The first sign is the lifeless, yellowish-green color of the foliage. Sometimes the yellowing is uniform; more often it is more intense on one side, and a lateral warping or curling of the stem and the leaves occurs (fig. 3). The lower leaves become yellow first, and the appearance of symptoms progresses upward. As the yellowed tissue ages it turns brown and becomes dead and brittle. Affected leaves drop prematurely, and normal growth is distinctly retarded. The water vessels in stems and leaves of diseased plants become yellow to dark brown. In many respects the disease resembles black rot (p. 15) and is often confused with it. One fairly reliable point of distinction is that in black rot the veins become black rather than brown and the smaller veins of diseased leaves are much more generally discolored.

The rapidity with which yellows progresses depends upon the degree of susceptibility of the host plant and the favorableness of the

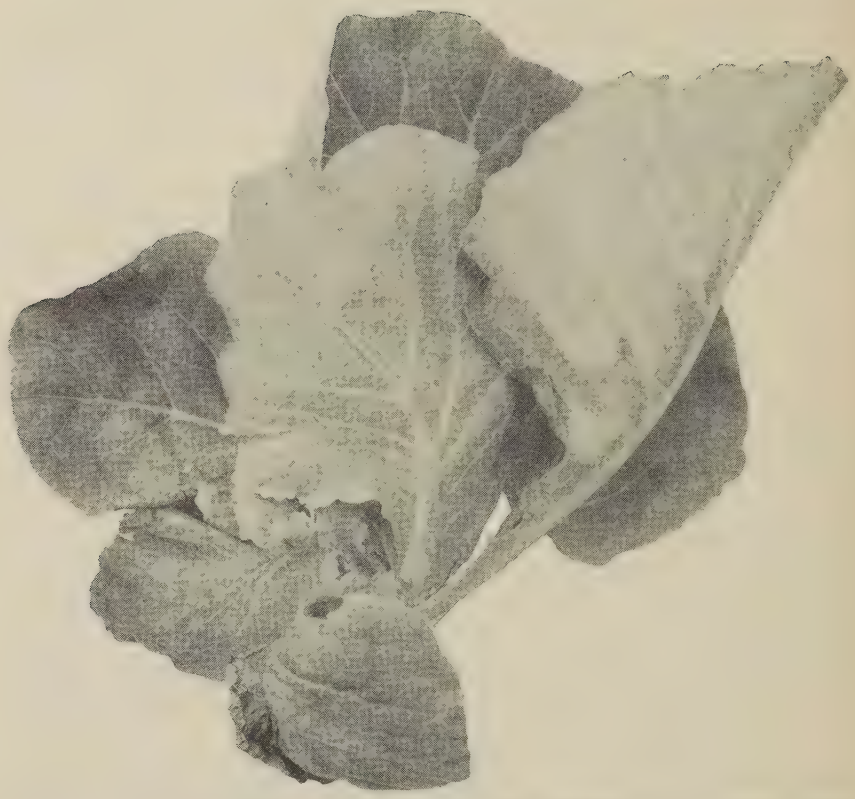

Figure 3.—A partly grown cabbage plant showing distortion of the lower leaves due to the development of yellows.

environment. In the latitude where yellows is most severe the conditions optimum for the development of the disease usually prevail during the first 3 or 4 weeks after the transplanting of the main crop of cabbage. The disease may then progress so rapidly that the most susceptible plants die within 2 weeks. Others may continue a sickly existence for a month or more. Some live through the summer, but head imperfectly. Relatively highly resistant plants or susceptible plants growing under cool climatic conditions may show the disease on one or two lower leaves which eventually drop; and the plants may recover and produce normal heads. The conditions favorable for yellows in early cabbage may not appear until the crop is approaching maturity; therefore, even though they are very susceptible, early varieties often escape the disease. The leaf symptoms on other members of the cabbage tribe closely resemble those on cabbage.

Causal Organism

The yellows organism is a fungus (*Fusarium oxysporum* f. *conglutinans* (Wr.) Snyder and Hansen) which is closely related to, but distinct from, those causing wilts of cotton, tomato, watermelon, cowpea, garden pea, and China-aster. It produces microscopic threads (mycelium), which grow in the soil and on dead-plant refuse. It

also produces two types of microscopic "seeds," or spores, one type being thin-walled and short-lived (conidia) and the other heavy-walled and capable of withstanding long periods of unfavorable temperature or drought. Many plant parasites do not persist long in the soil in the absence of their hosts, but the yellows organism, like that of clubroot, remains viable in the soil for many years. In fact, there is reason to believe that the yellows fungus and the related wilt fungi not only persist in the soil, but actually grow and increase in many soils quite independently of their respective host plants.

The yellows organism enters the plant almost entirely through the region of the young rootlets. However, it may enter through wounds in older roots incurred at the time of transplanting. It penetrates the young root tissue and migrates directly to the water-conducting vessels. It then progresses up the root and stem into the leaves, confining itself to the vessels until part or all of the plant dies. Then the mycelium may permeate the dead tissue and produce conidia on the surface. Occasionally conidia are produced within the water vessels. The characteristic browning of the vessels is associated with fungus invasion. Migration is largely upward, and little lateral spread from vessel to vessel occurs. The one-sided development of leaf symptoms and of those on the plant as a whole is thus associated with the invasion of certain vessels by the fungus and the freedom of others from it. The browning of vessels and the yellowing of leaves commonly occur well in advance of the penetration of the fungus. In fact, the disease condition is apparently not due to the plugging of the vessels by the fungus but rather to the toxic substances produced in the vessels at the time of the fungus invasion and carried to the stems and leaves by the nutritive sap which moves from the roots toward the outer extremities of the plant.

Conditions Favoring Yellows

As already pointed out, yellows is a warm-weather disease. It is almost completely checked when the average soil temperature is below 60° F. Its appearance is hastened and its severity increased as the air- and soil-temperature averages rise above that point. When the average temperature is 90° or above, yellows development is retarded; but since this condition does not prevail for long periods in sections where cabbage is profitably grown there is no practical check of the disease by higher temperatures.

Soil moisture and soil reaction have little influence on yellows, and the fungus establishes itself readily in a wide range of soil types.

Host Resistance to the Yellows Fungus

Varieties of cauliflower, broccoli, and brussels sprouts naturally have a high degree of resistance to yellows. Varieties of cabbage with the exception of those developed for yellows resistance, kohlrabi, and kale are generally very susceptible to the disease.

In most varieties, however, at least a small percentage of the plants survive on thoroughly infested soil under optimum conditions for the disease. These resistant survivors have become the basis of selection of resistant varieties of cabbage, many of which are now in commercial use. In the course of breeding for yellows resistance two types

of resistance have come to be recognized. Since they are important in determining the value of a given yellows-resistant variety their main points of distinction are indicated. They are referred to as type A and type B (fig. 4).

Since type A is controlled by a single hereditary factor, it is relatively simple to obtain lines that run true for this type of resistance; in such lines the resistance remains fixed if outcrossing with other varieties is not permitted. Plants that have type-A resistance develop no typical symptoms of yellows even at high temperatures.

Type-B resistance is controlled by a complex set of hereditary factors; it is very difficult, if not impossible, to fix this character in a variety so that it will run true in successive generations. Moreover, plants containing type-B resistance differ from one another in the "dosage" of resistance they contain. As the average soil temperature rises, this type of resistance is progressively less effective until, at 77° F. (constant soil temperature) or above, type-B-resistant plants succumb with typical yellows on infested soil, whereas type-A-resistant plants remain perfectly healthy.

In the field, therefore, type-A-resistant varieties remain free from yellows even during very warm summers. Type-B-resistant varieties are commercially successful in moderately warm seasons, but as the temperature increases, a large percentage of individual plants show varying degrees of disease development; heavy losses may result if a protracted high-temperature period prevails.

Figure 4.—Resistance to cabbage yellows as shown in strains grown on naturally infested soil. At the right center, two rows of Penn State Ballhead, a very susceptible variety. At the left, two rows of Wisconsin Ballhead, which is entirely free from yellows, since all the plants carry type-A resistance. At the right, Wisconsin Hollander, which contains only type-B resistance; the stand is much better than that of the Penn State Ballhead, although a large percentage of the plants show mild to moderately severe stages of yellows.

It is obvious, therefore, that type-A-resistant varieties are most valuable, and these are being developed to meet the varied needs as rapidly as time and facilities permit. It is usually difficult to distinguish type-A- and type-B-resistant plants in the field, since they can be separated with certainty only if grown in the greenhouse on infested soil held at a constant temperature of 77° F. This method is used in breeding new varieties and can be used also to determine what percentage of seeds in a commercial resistant variety carry type-A resistance.

Control Through Use of Resistant Varieties

The yellows organism is not seed-borne; but, like the clubroot organism, it is readily transported by man, animals, implements, plants, bulbs, seed tubers, surface drainage water, and plant refuse. Since the organism persists indefinitely in the soil, crop rotation is ineffective. So far as cabbage culture is concerned, the disease has been brought under successful control by the development of yellows-resistant varieties. Since a wide range of resistant types now exists, they should be used exclusively in those regions where climatic conditions permit the development of the disease.

Resistant varieties in commercial use range from early- to late-maturing types. The days given in the varietal descriptions are the average number elapsing from the time of transplanting to the maturing of the heads; the plants of the first six varieties listed were set out at Madison, Wis., in the middle of May and those of the other varieties in the second half of June. This period will, of course, vary with the season, locality, and method of propagation. It is useful here chiefly in giving a basis for comparing the rates of maturing of the several varieties described herein.

Wisconsin Golden Acre.—60 days. Developed by the Department of Agriculture and the Wisconsin Agricultural Experiment Station. Introduced in 1940. Selected from Golden Acre (a name now applied generally to the early-maturing strains of Copenhagen Market). Heads globular. Plants conforming closely to Golden Acre in type. Maturing 2 to 5 days earlier than most strains of Golden Acre. Authentic seed stocks testing close to 100 percent type-A resistance.

Resistant Detroit.—67 days. Introduced in 1936 by Ferry-Morse Seed Co. Selected from Golden Acre. Heads globular (fig. 5, *B*). Plant type conforming closely to that of acceptable stocks of Golden Acre. Maturing a little later than the earliest strains of Golden Acre and about a week later than Wisconsin Golden Acre. Original stocks testing about 80 percent type-A resistance and new stocks now coming into use close to 100 percent.

Jersey Queen.—67 days. Developed by the Department of Agriculture and the Wisconsin Agricultural Experiment Station. Introduced in 1932. Selected from Jersey Wakefield and practically identical with it in type and season. Heads pointed (fig. 5, *A*). Plants small, permitting close planting, and conforming to the smaller headed strains of Jersey Wakefield. Authentic seed lots testing close to 100 percent type-A resistance.

Racine Market.—80 days. Developed by the Department of Agriculture and the Wisconsin Agricultural Experiment Station. Introduced in 1935. Selected from Copenhagen Market. Heads globular. Plant type similar to that of the parent variety except for leaf and head color, which is blue green rather than yellow green. Heads maturing more slowly and more satisfactorily than those of Copenhagen Market and remaining standing without bursting. Authentic stocks testing close to 100 percent type-A resistance.

Marion Market.—85 days. Developed by the Department of Agriculture and the Wisconsin Agricultural Experiment Station with the aid of the National Kraut Packers' Association. Introduced in 1927. Selected from Copenhagen Market but distinct from that variety in its later maturity, greater size of plant and head (fig. 5, *C*), and bluer cast of foliage. Widely used as a midseason cab-

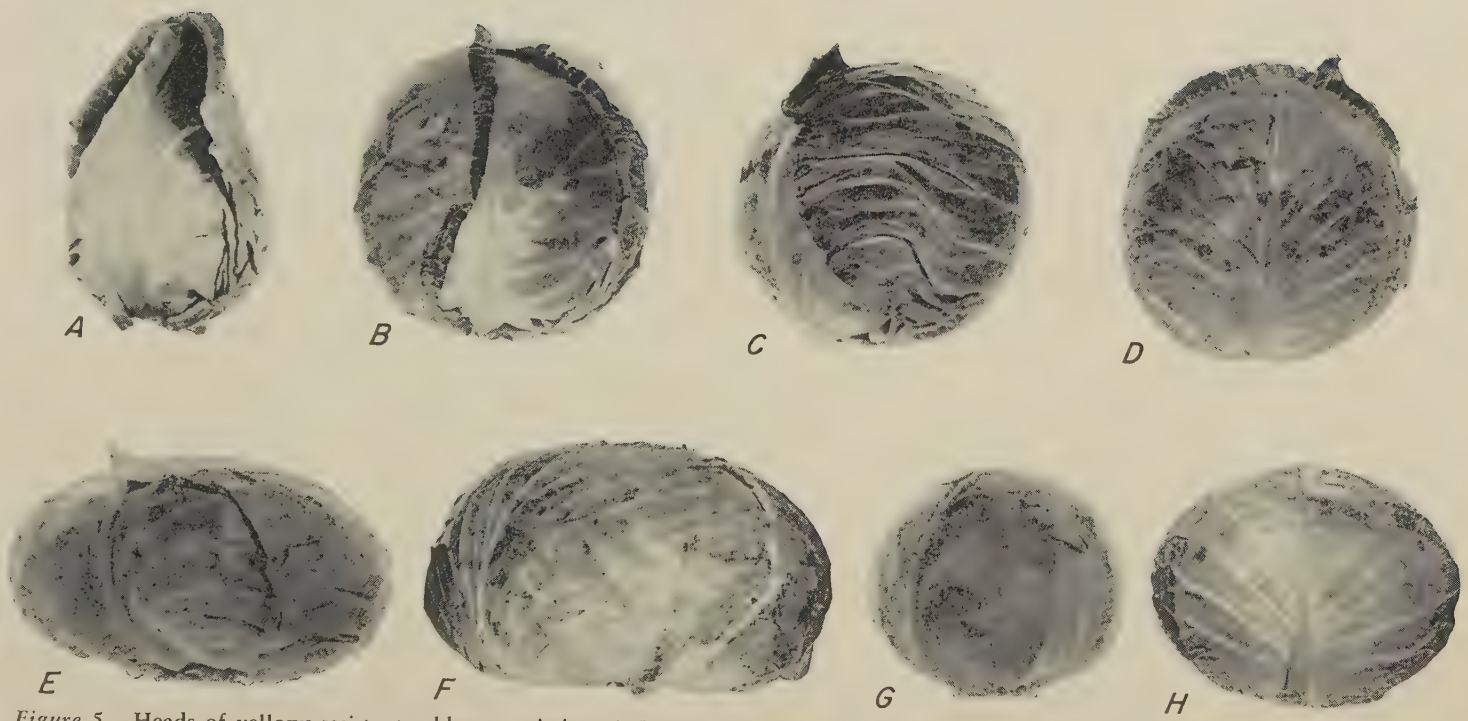

Figure 5.—Heads of yellows-resistant cabbage varieties: *A*, Jersey Queen; *B*, Resistant Detroit; *C*, Marion Market; *D*, Globe; *E*, All Head Select; *F*, Improved Wisconsin All Seasons; *G*, Improved Wisconsin Ballhead; *H*, Wisconsin Hollander.

bage for market and sauerkraut in the North and as a winter-shipping cabbage in the South. Authentic stocks testing 95 to 100 percent type-A resistance.

Globe.—88 days. Developed under the same auspices as Marion Market. Introduced in 1927. Selected from Glory of Enkhuizen. Midseason, roundhead type (fig. 5, *D*), requiring a few days longer to mature than Marion Market but suited to the same market requirements. Core relatively shorter than that of other roundhead varieties. Authentic stocks testing 95 to 100 percent type-A resistance.

All Head Select.—85 days. Developed under the same auspices as Marion Market. Introduced in 1927. A flathead type (fig. 5, *E*), selected from All Head Early. Midseason cabbage used for the southern shipping market and for early sauerkraut manufacture in the North. Authentic stocks testing 95 to 100 percent type-A resistance.

Wisconsin Ballhead.—91 days. Developed by the Department of Agriculture and the Wisconsin Agricultural Experiment Station. Introduced in 1935. Selected from Danish Ballhead. Practically identical with the latter in type and season; roundhead; short stem; blue foliage. Suitable in the North for early-fall shipping; when planted so as to mature late enough, suitable for storage. Plants not so large as those of Wisconsin Hollander, permitting closer planting; heads also smaller. Authentic stocks testing close to 100-percent type-A resistance.

Wisconsin All Seasons.—92 days. Developed by the Wisconsin Agricultural Experiment Station. Introduced in 1921. Late and very irregularly maturing, drumhead variety similar to All Seasons. Suitable for late-fall market and used somewhat for the southern winter crop; used most widely in the North for the late pack of sauerkraut. Most of the individual plants containing type-B resistance; up to 20 percent of them containing type-A resistance; under very high summer temperatures sometimes showing a considerable percentage of yellows.

Improved Wisconsin All Seasons.—92 days. An improved selection of Wisconsin All Seasons. Released by the Department of Agriculture and the Wisconsin Agricultural Experiment Station for increase in 1947. Similar in maturity and general plant characters to Wisconsin All Seasons, but plants of this variety are very uniformly like those of the most desirable type of the mother variety. Original stock testing 100-percent type-A resistance. (See fig. 5, *F*.).

Improved Wisconsin Ballhead.—97 days; maturing slightly later than Wisconsin Ballhead. From a cross between Wisconsin Ballhead and Wisconsin Hollander. Released for increase in 1946. Authentic stocks testing close to 100-percent type-A resistance. (See fig. 5, *G*.)

Wisconsin Hollander.—113 days. Developed by the Wisconsin Agricultural Experiment Station. Introduced in 1916. Selected from Danish Ballhead; 10 to 14 days longer in season than the latter and producing larger, flatter heads (fig. 5, *H*). Excellent storage cabbage, used widely in the northern part of the yellows zone. Resistance all of type B; the variety therefore not suitable for the warmer parts of the yellows zone, where under extreme warmth it may succumb rather heavily to yellows. Strains containing type-A resistance being developed.

Red Hollander.—113 days. Developed by W. J. Hansche, of Racine, Wis. Roundhead, late, red variety. Suitable for winter storage. Originally containing largely type-B resistance, but improved by commercial breeders so that it now contains a high percentage of type-A-resistant plants.

Resistant Flat Dutch.—116 days. Developed by Wisconsin Cabbage Seed Co. Introduced in 1942. Selected from Late Flat Dutch; type and time of maturity practically identical with those of the latter variety. Suitable for very late home use and sauerkraut production. Most individuals in authentic stocks containing type-B resistance; up to 30 percent containing type-A resistance.

Bugner.—120 days. One of the first resistant varieties developed in North America; selected by a Mr. Bugner, a gardener in the vegetable-growing district near Chicago, Ill., where it has been used extensively for more than 30 years. Ballhead or Hollander type, somewhat longer in season than Wisconsin Hollander. Heads very large, flattened, of excellent keeping quality. In extremely warm seasons often showing high percentage of yellows. Resistance all of type B; degree of resistance different in different strains.

BLACK ROT

Black rot occurs on all the cultivated crucifers and may affect some of the wild species. It finds congenial climatic conditions in many

localities, and since the causal organism is seed-borne, it has been distributed to many parts of the world. Since the organism does not persist indefinitely in the soil and depends upon the seed for distribution, the disease is decidedly sporadic. When it becomes established early in the growing season and favorable environment prevails, it may become extremely destructive, rendering a large percentage of cabbage plants incapable of producing marketable heads and making the remainder of the crop unsafe for storage or shipment. Cauliflower is one of the most susceptible hosts, and it requires the greatest care and precaution to grow it free from this disease.

Characteristics

Plants may be affected with black rot at any stage of their growth. Black rot is primarily a disease of the above-ground organs. The below-ground storage organs of fleshy-rooted crucifers (turnip, rutabaga, radish, and horseradish) may be affected, however, and a dry rot may occur. This is commonly followed by bacterial soft rot (p. 22).

Infection takes place primarily through water pores at the margin of the leaf. The progress of the disease from this point can frequently be traced through the veins of the leaf (fig. 6) by the blackening of the bundles. Marginal infection is followed by browning and drying of the infected areas of the leaf. Invasion also commonly occurs through wounds made on the leaf by biting insects. The organism progresses down the leaf to the main stem, where it may advance up or down. As it goes up the stem younger leaves are invaded. The affected bundles in leaf or stem are easily recognized in cross section by their blackened appearance, and often they can be traced through individual leaves of the cabbage head. If plants are infected while still young, dwarfing or one-sided growth commonly occurs. Affected leaves drop prematurely. In extreme cases heading is prevented. Black rot does not cause a soft rot of affected cabbage or cauliflower heads, but it opens the way for soft rot bacteria (p. 22); consequently, soft rot symptoms are common in association with black rot. For this reason it is dangerous to store cabbage heads or turnip or rutabaga roots from fields where black rot occurs.

There are some points of resemblance between yellows and black rot which often lead to confusion. Both cause discoloration of the bundles, and both may bring on one-sided development of the leaves or of the whole plant. The bundles affected with black rot are black in the main, and in the later stages they are commonly surrounded by cavities due to the break-down of surrounding cells. With yellows the bundles are brown and no cavities occur.

Causal Organism

The black rot organism is one of the bacteria (*Xanthomonas campestris* (Pam.) Dows.). These minute organisms are carried by insects, spattering rain, surface drainage water, and possibly by wind, or with wind-borne particles of dust. They are able to swim about in liquid; and, when they come in contact with drops of liquid that collect on the margins of leaves or about insect wounds, they enter the water pores or wounded tissue. They are able to penetrate the tissue until they reach the water-conducting vessels, and from then on they

multiply in this channel and progress chiefly through it. They may be carried over from year to year in or on seeds from infected host plants or in diseased-plant refuse.

Conditions Favoring Black Rot

The initial spread of the parasite usually occurs in crops started in seedbeds. Occasional plants become diseased from seed or soil, and there the germs multiply and become available for spread. Spattering water from rainstorms or artificial sprinklers is the chief means of dissemination. The amount of such spread determines how widely the plants are infected before they are transplanted. Infected lower leaves usually drop off, and plants commonly show little or no external sign of the disease, though internally infected when transplanted.

Figure 6.—Symptoms of black rot of cabbage which result from invasion of the marginal water pores of the leaf by the causal organism and its migration downward through the water vessels.

Infected plants may grow normally with little or no external sign of disease for 3 to 6 weeks after they are transplanted; after that period the lower leaves gradually develop symptoms owing to the migration of the organism from the main stem. Thus fields of cabbage or cauliflower may rather suddenly show large percentages of plants with black rot in midseason. The epidemic is due to favorable conditions for early spread in the seedbed and the slow subsequent development of the parasite in the plants.

Black rot is practically absent in the Pacific coast cabbage-seed-growing sections. Its retardation is attributed to the lack of heavy spattering rains during the period in which cabbage plants are in the seedbed and the consequent unfavorable conditions for the spread of the parasite. Cabbage seed from those sections is generally free from the black rot organism.

Control

The major points in the control of black rot are as follows:

(1) Treat the seed before planting with the hot-water treatment described on page 2.

(2) Use clean seedbeds. The black rot organism lives in the plant refuse in the soil during one and possibly two northern winters. It is therefore essential to grow noncruciferous crops for two seasons on soil used for crucifers or to sterilize the soil between cruciferous crops. In Southern States avoid making seedbeds in proximity to oversummering crucifers such as collards, kale, turnip, and rutabaga.

(3) If seedbeds are watered artificially, avoid sprinkling the foliage, since to do so aids in disseminating the black rot organism. It is preferable to irrigate in furrows between the rows.

(4) Practice rotation in the field so that at least 2 years, and preferably 3, elapse between cruciferous crops.

BLACKLEG AND DRY ROT

Blackleg is important on members of the cabbage tribe and on turnip and rutabaga. A strain of the blackleg organism attacks the last two crops in Europe and in New Zealand, where for many years it has caused a serious dry rot in storage. This phase has now been reported in the United States and Canada. Blackleg is found most commonly on cabbage, cauliflower, broccoli, and brussels sprouts and occasionally on other members of the cabbage tribe. When the disease gains a start in the seedbed it may be very destructive in the field.

Characteristics

The earliest conspicuous symptoms occur in the seedbed 2 or 3 weeks before transplanting time. Spots occur on leaves and stems. The leaf spots appear as inconspicuous, indefinite, pallid areas that gradually become well-defined spots with ashen-gray centers in which innumerable black dots much smaller than a pinhead are scattered irregularly (fig. 7). These are the fruiting bodies (pycnidia) of the fungus. Similar spots occur on the stem, where they are sunken and are often surrounded by a purplish border. The stem lesions gradually enlarge after the plants are removed to the field, extending to the underground portions. In fact, incipient, invisible infections at transplanting time gradually develop into subterranean stem and root lesions. The fibrous root system may be largely destroyed, although

Figure 7.—Blackleg of cabbage.

new roots sent out above the lesions serve to keep the plant alive. Often badly affected plants survive until fair-sized heads form, when they topple over as the increasing top weight overbalances the gradually decaying root anchorage. Many plants wilt abruptly and die. The wilting leaves tend to remain attached to the stem, instead of dropping as in black rot and yellows. As root corrosion progresses, the still-turgid plants often show a reddish color of the outer leaves, particularly near the margins. Other types of root injury may cause similar discoloration, however. Pycnidia are not common to subterranean parts until the plants are dead and the succulent tissue has completely decayed.

Leaf spots continue to appear, their number depending on favorableness of the environment. The blackleg fungus may invade heads in storage, but it does not cause serious decay. It attacks the branches, leaves, and pods of seed plants and invades the seeds. Many seeds when attacked in their early formative period become shriveled and nongerminable; others, only slightly affected, carry dormant mycelium in the seed coat and remain viable. Young seedlings are attacked either on the cotyledon, which commonly carries the infected seed coat above ground, or at the base of the stem (hypocotyl) if the seed

coat remains below the ground. In any case, seedlings attacked early in the season die promptly and furnish an early crop of pycnidia, from which the spores may spread to surrounding plants.

When the turnip dry rot strain of the blackleg fungus affects turnip and rutabaga, leaf and stem lesions similar to those on cabbage develop but the typical blackleg cankers at the ground line may or may not occur. Root cankers may appear before harvest. Contamination may occur at harvest and as invasion continues in storage a dry rot follows.

Causal Organism

The blackleg organism is a parasitic fungus (*Phoma lingam* (Fr.) Desm.). It is carried in the seed and persists on plant refuse for 1 or 2 years. Damage to the host is done by the mycelium that penetrates the tissue, killing as it goes. The mycelium in the dead tissue gives rise to the dark pycnidia, which are flask-shaped, with openings to the exterior of the leaf or stem. Myriads of thin-walled spores are formed within the pycnidia, where they remain embedded in a gelatinous matrix during dry weather. Moisture on the lesion in the form of rain or dew is absorbed by the matrix, which expands rapidly, forcing its way through the opening of the pycnidium to the exterior and carrying spores (pycnospores)) with it.

The spores germinate within a few hours and penetrate the host if moisture is present. If the plant surface dries off quickly the spores die. It is thus evident that a moist period of several hours is essential for spore expulsion and reinfection, while spattering rain is essential to carry the viable spores from diseased to healthy plants.

Conditions Favoring Blackleg

Initial infection in the seedbed starts with occasional plants infected from the seed or the soil. The blackleg fungus usually kills them promptly and fruits. Further spread is dependent on moist periods and spattering rain. Epidemics are usually to be traced to rapid spread in the seedbed. This often occurs just before transplanting, and the new infections, being invisible, appear later in the infected field. The Pacific coast cabbage-seed-growing sections fortunately have a climate during the seedbed period that tends to check the spread of blackleg from any initial centers; consequently, the cabbage-seed crop in this section is usually free from blackleg, but the organism has been found recently on several lots of seed from those sections. The turnip- and rutabaga-seed crops from this section also appear to be relatively free from the dry rot organism.

Control

The measures of control outlined for black rot (p. 18) are effective in the control of blackleg.

RHIZOCTONIA DISEASE

The fungus that causes the rhizoctonia disease is widely distributed in the soil. It attacks a great many species of plants and causes a variety of pathological effects. Probably there are numerous strains, which vary in the hosts that they attack. The strains which attack the potato, for instance, do not ordinarily affect crucifers and vice versa. With its many effects the rhizoctonia disease is of major importance on cruciferous crops.

As cruciferous plants are attacked by the rhizoctonia disease at different stages, the symptoms are grouped accordingly.

Damping-off.—*Rhizoctonia* is one of the more common fungi that attack young seedlings, invading them at the base of the young stem (hypocotyl) or at the soil line. The tissues become water-soaked and rapidly collapse, and the tender young plants topple over and die. A number of other soil fungi affect young seedlings in a similar manner.

Wire stem.—Young seedlings that are attacked less vigorously or when they are somewhat older have a much greater chance of warding off the fungus. Later attacks are less serious because the young stem has begun to thicken and grow in diameter and to slough off its outer cells. At this stage plants previously attacked by *Rhizoctonia* are brownish to black just above and below the soil line; the stems are usually somewhat smaller than normal but tough and woody. This type of disease is known as wire stem. Affected plants may recover and grow normally, but under some conditions the fungus may continue to retard their growth after they are transplanted.

Bottom rot.—Bottom rot occurs in midseason, either as a carry-over from wire stem or from new infection. The lower leaves droop, decay, and turn dark but do not drop. Plants may recover and produce normally. In cabbage, bottom rot may develop into head rot.

Head rot.—Head rot of cabbage develops between early head formation and maturity as a dark firm decay at the bases of outer leaves and heads (fig. 8). The outer leaves of the head become wilted and pallid and brown to black near the main stem. Mycelium becomes conspicuous on decayed tissue and between the head leaves, on which it produces dark, sunken spots. Firm, persistent, dark decay continues in storage and transit.

Root rot.—Root rot of turnip, rutabaga, and radish occurs before harvest and in storage. In greenhouse culture of radishes a rather

Figure 8.—Rhizoctonia head rot of cabbage.

soft decay of partly grown roots is common; gray surface mycelium and dark-brown kernellike bodies (sclerotia) form on the affected tissue. A similar brown and spongy decay occurs on turnip and rutabaga roots, particularly in storage. The cobwebby mycelium and brown sclerotia help to distinguish the disease from root rots caused by other organisms.

Causal Organism

The causal fungus (sterile form, *Rhizoctonia solani* Kuehn; spore-forming stage, *Pellicularia filamentosa* (Pat.) Rogers) is common in soil. Its occurrence as a parasite depends largely on the susceptibility of the host and the favorableness of the environment. It attacks chiefly young succulent tissue and dormant storage tissue. The mycelium is long-lived; as the food in the decaying tissue becomes exhausted it rounds up into dense, brown, kernellike bodies (sclerotia), which may resist unfavorable conditions for an indefinite period. Spores are seldom formed. Occasionally a superficial white mycelial weft on the lower side of leaves near the soil bears thin-walled, short-lived spores. As pointed out previously (p. 20), the fungus has a number of strains that are specialized on certain groups of plants.

Control

The important measures for the control of the rhizoctonia disease follow:

(1) When plants are grown in hotbeds or coldframes treat the soil with steam or formaldehyde. Crucifers are very sensitive to formaldehyde; therefore allow the soil treated with it to stand 2 or 3 weeks before planting crucifers in it.

(2) Mercuric chloride (1–2,000) drench at the base of plants in the seedbed, as used to kill maggot eggs, is helpful in reducing wire stem.

(3) Sort out plants affected with wire stem when transplanting.

(4) Do not plant crucifers in short rotations on sites where bottom rot, head rot, and root rot have occurred.

Formaldehyde solution is irritating to the skin. Hands should be protected with gloves. Surplus solution should be carefully disposed of. Vessels and clothing should be thoroughly cleaned.

Mercuric chloride is a deadly poison; great care therefore must be taken in mixing and handling the solution to prevent any contact with the mouth, eyes, or nostrils. Unused solutions should be buried in the ground at least 1 foot deep. All vessels must be thoroughly cleaned before they are used again, and all clothing should be thoroughly cleaned. Any surplus chemical should be plainly labeled and stored out of the reach of children and animals.

BACTERIAL SOFT ROT

Characteristics

The loss from bacterial soft rot alone or in combination with other rots is considerable both in storage and in transit (p. 37). It is occasionally destructive in the field, especially if it follows black rot. Freezing injury is commonly followed by soft rot.

Bacterial soft rot of cabbage is characterized by a soft, mushy, almost slimy decay, which after entering, generally at the surface or

base of the head (fig. 9), spreads rapidly through the whole plant. The soft rot bacteria as a class are marked for their ability to destroy plants very quickly under favorable temperature and moisture conditions. They seldom affect uninjured plants, as they require a wound or other injury in which to gain a foothold or they appear in conjunction with black rot or black leaf spot. Infection takes place in the field where considerable damage may result, but the greatest destruction to cabbage is caused in storage houses or in transit. The storage phase of this disease is discussed in the section on Transit and Storage Diseases (p. 35).

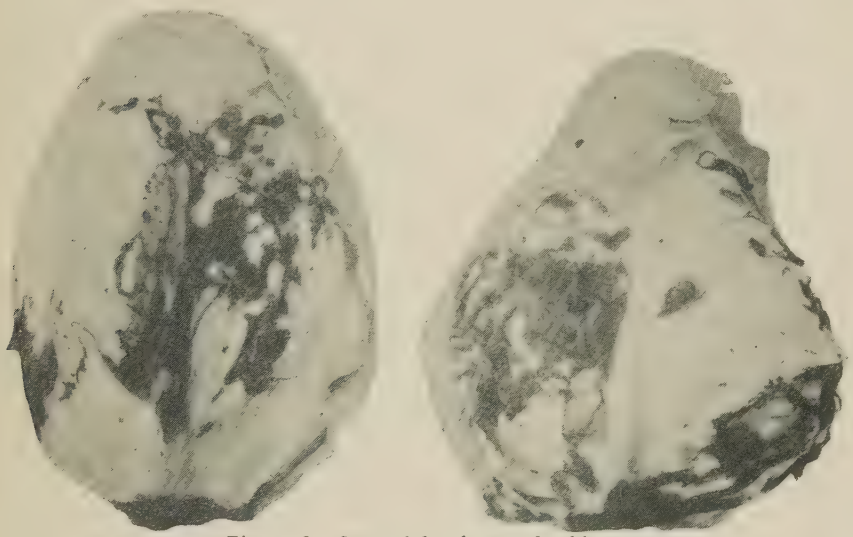

Figure 9.—Bacterial soft rot of cabbage.

Causal Organism

Soft rot in cabbage and related crops is due to bacteria belonging to a group usually referred to as the soft rot bacteria, which may attack carrots, turnips, celery, and other vegetables. *Erwinia carotovora* (L. R. Jones) Holland, which causes bacterial soft rot of cabbage, is a common example of these bacteria.

Although these bacteria are universally present, they require special conditions to gain a foothold in plant tissue. Not only are wounds in the tissue necessary, but the conditions must be such that the wounds are not corked over before soft rot sets in. The gnawing action of maggots keeps the tissue freshly wounded and predisposed to soft rot. Maggot larvae ingest the bacteria, which remain in their bodies until the adult flies are formed; the flies carry the bacteria to new locations and lay contaminated eggs on healthy plants. Newly hatched maggots thus are provided with soft rot bacteria as they begin to feed. In fact, the bacteria aid the larvae by making the raw plant tissue more digestible. Cabbage plants approaching the heading stage are often attacked by maggot larvae on the main stem at the base of the head. Such insect injuries may become the forerunner of soft rot in the field.

Control

Various measures can be used to avoid soft rot. Cabbage and other cruciferous crops should be carefully selected for storage or shipment and handled so that they will be injured as little as possible, and all surface moisture should be allowed to evaporate. Temperatures slightly above freezing and ventilation adequate to prevent high relative humidity are advisable in storage. The same precautions should be observed in long-distance transit.

WATERY SOFT ROT AND WHITE BLIGHT

Characteristics

Watery soft rot is most common in the Gulf coast region, where it occurs on crucifers and many other vegetable crops, especially lettuce, celery, cucumber, and carrot. The earliest symptoms of this fungus disease, also known as drop, are indicated by water-soaked areas over the stem and lower leaves. The wilting of the lower leaves is followed finally by the collapsing of the whole plant into a shapeless mass. The plant may succumb to the disease in a few days, or it may live 2 weeks or more. In and about the decayed region a dense white cottony mass of mycelium accumulates. In the later stages of the disease irregularly shaped, hard, black bodies, the size of a mustard seed or larger, can be found scattered among this cottony mass. These bodies (sclerotia) are almost sure evidence of the disease (fig. 10).

Decay of the harvested crop may continue; in fact, new infections may show up later in plant parts that appear healthy at harvesttime. Usually these result merely from the progress of incipient infections to visible size. The fungus causes a soft rot of storage organs such as cabbage heads and turnip roots, which may be distinguished from bacterial soft rot of crucifers by the lack of sulfurous odor, the presence of

Figure 10.—Watery soft rot of cabbage.

cottony mycelium in the decayed tissue, and the prompt drainage of water from the rotting tissue. In contrast the water is retained in a slimy mass when the rot is caused by the bacterial soft rot organism. For that reason on the market bacterial soft rot is often called slimy soft rot to distinguish it from watery soft rot.

The watery soft rot fungus causes the disease of seed plants of cabbage, turnip, and rutabaga known as white blight. In the second growing season, when these plants send up seedstalks, the spores (below) discharged from fruiting bodies at the soil surface find the points of attachment of leaves and the main stem particularly favorable for germination. Water from dew or rain tends to accumulate there, and fallen petals deposited there decay and provide nutriment for the spores. Infection of the stem follows. A light-colored lesion develops, extends above and below the leaf axil, and eventually girdles the stem. The fungus progresses even farther in the pith of the stem, and sclerotia are formed abundantly there. The affected stem withers and becomes unfruitful. Therefore, white blight sometimes is very destructive to seed crops of crucifers.

Causal Organism

The watery soft rot fungus (*Sclerotinia sclerotiorum* (Lib.) DBy.) forms a coarse, white growth in and about the decayed region of the plant that it attacks; later the hard, black bodies (sclerotia) develop from the mycelium and keep the fungus alive during periods of unfavorable environment. In the spring they send up small mushroom-like bodies (apothecia) bearing an abundance of microscopic spores (ascospores), which are discharged into the air; when these spores come in contact with the moist surface of the host plant, they germinate and cause infection.

Control

Control of watery soft rot is difficult. Rotation with crops not attacked by the fungus, such as corn, cotton, crotalaria, peanuts, and sweetpotatoes, is advisable.

BLACK LEAF SPOT

Characteristics

Black leaf spot, sometimes called black mold, or brown rot, occurs as a leaf spot of cabbage, cauliflower, collards, and a number of other crucifers. Stems and pods of seed plants of crucifers are commonly affected. It causes a mold of cabbage heads in storage and a brown rot of cauliflower heads in transit. As a field disease it is ordinarily of minor importance, but in storage or transit the organism may be very destructive.

In the field it appears on the lower or outer leaves of the maturing plants as distinct, roundish black spots commonly marked with concentric brown zones (fig. 11, *B*). These spots range from one-fourth to more than one-half inch in diameter. On stems and pods the spots are irregular in size and shape. They are distinguished from blackleg spots (fig. 7) and ring spots (fig. 11, *A*) by the absence of the numerous dots (pycnidia) in the diseased area. In storage these spots may blend together on cabbage heads until the outer leaves are covered and

entirely blackened by the moldy development. On the curd of cauliflower the disease appears as brown spots which turn olive green with age.

Causal Organism

Black leaf spot is caused by a fungus [2] which overwinters on cabbage refuse or on the seed. The black mold that develops on the leaf spots or on cabbage or cauliflower heads consists largely of the dark-colored spores of the organism. These are readily disseminated by wind or water, and they germinate in water, thus invading healthy plants and causing new infections.

Figure 11.—A, Ring spot on cauliflower; *B,* black leaf spot of cabbage.

Control

Black leaf spot ordinarily is not sufficiently important in the field to warrant the practice of specific remedial measures. The mercuric chloride treatment is not effective; and the hot-water treatment recommended for blackleg (p. 2) is necessary to rid the seed of the organism. Because the disease is most destructive in storage and transit, care should be taken to handle the crop so as to minimize the trouble. Heads should be handled carefully to avoid bruising, and surface moisture should be allowed to evaporate before storage. The storage house should be kept at 33° to 34° F., and ample ventilation should be provided to reduce humidity.

[2] The organism commonly associated with the disease is *Alternaria brassicae* (Berk.) Sacc. A closely related species may also cause similar symptoms.

RING SPOT, OR BLACK BLIGHT

Characteristics

In North America ring spot is most prevalent on the Pacific coast, where it affects cauliflower, cabbage (including seed plants), kale, and certain other crucifers. It appears in the early stages as dark-purple spots, which gradually enlarge, often becoming an inch or more in diameter on the leaves (fig. 11, *A*). The older spots are dark brown with light-green borders. In advanced stages minute black specks appear in the dead parts of the spot, resembling very much those of blackleg. They are to be distinguished from the latter by being much smaller and more numerous and thus more closely crowded. The disease appears on the stems and pods of the seed plants as small spots or as long purple streaks. It is sometimes destructive to the cabbage-seed crop in the Puget Sound section, where it is commonly known as black blight. The chief damage is done to cauliflower, on which ring spot causes defoliation and losses in transit.

Causal Organism

The ring spot fungus (*Mycosphaerella brassicicola* (Duby) Lind.) produces on the lesion bodies which appear as black specks to the unaided eye. These are known as spermagonia; within these are produced myriads of microscopic bodies known as spermatia. The spermagonia resemble the pycnidia of the blackleg fungus (p. 20) and the spermatia its pycnospores. The spermatia differ from the pycnospores of the blackleg fungus, however, in that they do not germinate in water and do not serve as means of dissemination of the fungus. Later there appear in the lesions in which the spermagonia were formed, somewhat larger fruiting bodies (perithecia) which contain spores (ascospores). The ascospores are discharged into the air when the perithecia become moist. The ring spot fungus, then, depends on moisture for ascospore discharge and upon air currents for dissemination. In the dry midsummer period on the Pacific coast little development and spread occur, but fall and winter rains favor spore discharge and infection. The ring spot fungus becomes most destructive on winter cauliflower in the coastal valleys of California and on the seed plants of cabbage in the sections along the coast in California, Oregon, and Washington. In seed-growing sections the greatest source of infection is likely to be dry stalks and leaves from threshed seed plants. Fall rains provide favorable conditions for ascospore discharge; at that time the first-year plants of the next seed crop are readily infected. The causal fungus may then continue to spread through late fall and the following spring. General infection of seed pods results in reduced yields and inferior seed.

Control

The chief means of control of ring spot is to destroy during the dry summer all crop refuse which may provide ascospores with the onset of fall rains. In seed-growing sections it is necessary to burn straw piles after threshing the seed crop, to plow seed fields soon after harvest, and to isolate the seedbed from maturing seed fields.

POWDERY MILDEW

Characteristics

Powdery mildew appears as a white powdery fungus growth in spots or more or less completely covering the upper surfaces of leaves and the stems of cruciferous plants. It occurs more abundantly in semiarid regions or in more humid regions after a protracted dry spell.

Causal Organism

The powdery mildew fungus (*Erysiphe polygoni* DC.), attacks many plants; one or more of its numerous strains are probably confined to the crucifers. The powdery material on the host consists of the spores (conidia) and the branch of the mycelium on which they are borne. Later black bodies smaller than a pinhead appear embedded in the mycelium. They are fruiting bodies (perithecia) containing another type of spores (ascospores). Perithecia may survive periods of unfavorable environment and upon the return of favorable conditions produce another crop of ascospores. This stage of the fungus is the one whereby it survives from one crop season to the next.

Control

Ordinarily powdery mildew is of no economic importance on crucifers. Should remedial measures become necessary, finely divided sulfur dust gives adequate control.

DOWNY MILDEW

Characteristics

Downy mildew differs from powdery mildew in that the causal fungus is conspicuous on the lower surfaces of leaves, on which in a humid climate it forms a fluffy, downy growth, usually in well-defined areas. Often the effect upon the leaf tissue is such as to cause yellow spots on the upper surface above the mildew growth on the lower surface. The spots may be small, purplish, and numerous when abundant infections have occurred, but enlargement of the spots is checked by a hot, dry environment. The exposed leaves of maturing cabbage heads are sometimes affected by many small spots of mildew, which predispose them to soft rot in transit. Stems and seed pods are also affected, the chief symptom being dark-purplish spots irregular in size and shape.

The causal fungus thrives best in a cool, moist environment and is therefore found chiefly in humid regions. In the Gulf coast and Pacific coast sections it is commonly destructive to cabbage seedlings in seedbeds or coldframes. Damage to cabbage in the field is not serious except in the winter crops on the Gulf coast, where it predisposes the outer leaves of the heads to bacterial soft rot in transit.

Causal Organism

The downy mildew fungus (*Peronospora parasitica* Fr.) affects many cruciferous plants. It is made up of many strains, each restricted to certain groups of host plants. The mycelium penetrates the plant through the breathing pores (stomata) and grows between the host cells, gaining its nutriment from knoblike projections (haustoria) into the cells. It produces spores by first sending out

special branches on the surface of the lesion. These make up the mildew growth visible on the leaf surface. The thin-walled spores (conidia) are readily carried by air currents and are short-lived; but in relatively cool moisture they germinate promptly and produce fungus threads that enter the stomata and cause new infections. Within the tissue dark, heavy-walled resting spores (oospores) form. These can carry the fungus through long unfavorable periods. The fungus mycelium persists in perennial roots and in storage organs such as cabbage heads and turnip roots. In storage it causes in both a slow, dry decay that occasionally becomes important. In such cases the decay may be diagnosed by placing decayed parts in a moist chamber, where the fungus ordinarily fruits readily on the surface.

Control

In open seedbeds in sections where downy mildew is destructive the plants should be sprayed or dusted with Fermate or Spergon. The directions supplied by the manufacturers should be followed rigidly. In Mississippi, where seedlings are produced in coldframes, benzene vapor has proved effective. Growers who desire to use benzene are advised to ask their county agents about the latest methods.

WHITE RUST

Characteristics

White rust occurs on many wild and cultivated crucifers and is world-wide in its distribution. The white blisterlike pustules on leaves, stems, and seed pods break open and expose a white powdery mass consisting of spores of the causal fungus. These isolated pustules are seldom associated with any marked distortion of the plants. When the interior of young stems and flower parts are invaded, they grow to excessive size and are severely distorted. Flower petals, stamens, and ovaries grow to many times their normal size and can be recognized only by their relative positions.

White rust is common on radish, but ordinarily it is not destructive except in midwinter greenhouse crops. Horseradish is perhaps more seriously affected than any other crop in this country, since when the perennial roots become infected the normal growth is impeded. The infection of radish seed plants causes occasional loss. White rust is not known on cabbage in this country, but it occurs on this crop in Europe, where it also causes occasional losses to the seed crop. It occurs on cauliflower-seed crops in California, where it may be of economic importance.

Causal Organism

The white rust fungus (*Albugo candida* (Chev.) Kuntze) is closely related to the downy mildew organism. It also consists of several distinct strains, each confined to certain hosts. Relatively short-lived spores (conidia, or sporangia) are borne in the white pustules in chains on short branches of the mycelium. These conidia germinate best when it is cool; after a few hours in water they each give rise to several swimming spores. The latter come to rest on the crucifer leaf and send out tiny threads which enter the breathing pores. The fungus mycelium then grows between the cells and feeds by means of haustoria, as the downy mildew fungus does. The spore-bearing

branches form from the mycelium below the host epidermis, which is gradually raised as the pustules form. The latter remain shiny and blisterlike as long as the host surface is unbroken and retains the spores intact, but the epidermis eventually breaks and releases the conidia. The mycelium in young branches and in the flowers stimulates the host cells to multiply rapidly and abnormally, giving rise to malformations. In this tissue from the mycelium between the cells dark, thick-walled resting spores (oospores) are formed; these carry the fungus through unfavorable periods.

Control

Control measures have not been worked out for white rust.

Figure 12.—Upper surface of a cauliflower leaf, showing typical bacterial spot.

CAULIFLOWER BACTERIAL SPOT

Cauliflower bacterial spot occurs primarily on cauliflower, but it is occasionally found on cabbage. It occurs commonly on Long Island, N. Y., in the tidewater district of Virginia, and in the bay district of California; it has been observed also in various other parts of this country and abroad. Small brownish to purplish-gray spots sometimes irregular in outline occur on both surfaces of the leaf (fig. 12). A puckering of the leaf results when the midrib and larger veins are infected abundantly.

This disease is caused by a bacterium (*Pseudomonas maculicola* (McCul.) F. L. Stevens). It has been observed that the spot disease is most severe during cool, damp weather and is held in check when the warm, sunny days of late spring arrive.

Crop rotation should probably be practiced. Since the causal organism is probably seed-borne, the hot-water treatment of seed should be used.

BLACK ROOT OF RADISH

The white icicle type of garden radish is very commonly affected with black root, a dark-brown to black dry decay of the fleshy roots, which makes them unsalable. This disease is caused by a fungus (*Aphanomyces raphani* Kendr.), which normally inhabits the soil; the mycelium enters the fleshy root through the temporary wounds that are made when the small secondary roots push their way out. Once in the fleshy root, the fungus

progresses through the tissue and kills cells, which soon discolor. The thick-walled resting spores of the organism are formed in the tissue.

In the icicle radish the secondary roots emerge in two opposite zones—on the taproot and approximately halfway up the fleshy root. In these zones black root occurs. In globe types of radish the fleshy part formed is almost entirely from the lower stem (hypocotyl), and secondary root zones do not occur except at the base. As a result they are not noticeably affected. It is consequently necessary to avoid black-root-infested soil for radishes of the icicle type. Other cruciferous crops do not appear to be affected.

MOSAIC

Several viruses affect cruciferous crops. All are transmitted by aphids, or plant lice, and each has a distinct host range. Turnip is a host to all crucifer viruses so far described. Some affect hosts outside the crucifer family. In California cauliflower mosaic is due to one virus and cabbage black ring to another. In the Middle West and in the Pacific Northwest the mosaic of cabbage is due to the combined effect of two viruses; one of these is closely related to that associated with the cauliflower mosaic of California and the other to the black ring virus of California.

On cabbage the leaves of plants affected with mosaic show a mottle, resulting from lighter yellow and darker green areas than normal and so arranged as to give a mosaic pattern which may be so mild that it is readily overlooked. The most serious injury is stunting of the plant as a whole. Another serious effect is killing of some of the tissue, which turns black or brown. Necrotic areas occur as spots on the outer leaves and often throughout the mature head (fig. 13). Mosaic-affected seed plants may be severely stunted.

The cabbage mosaic viruses are carried from plant to plant by aphids and are probably spread chiefly by this means. They can be transferred from diseased to healthy plants, however, by injecting extracted sap from the former. The usual method of overwintering is in cabbage-seed plants and in cruciferous weeds such as shepherds-purse and pennycress.

In the Pacific Northwest mosaic has been very severe on the cabbage-seed crop. Extensive losses from this disease have been found to be due to the fact that seedbeds were commonly made in the same locality as the maturing seed crop. Infective aphids move from the maturing crop to the new seedbed. To break this continuous chain of increasing virus concentration it is necessary to make the seedbed in a locality free from seed crops and other infected crucifers. When this practice is followed, the damage from mosaic is reduced to a negligible amount.

DAMPING-OFF

Damping-off of seedlings of many crops is common. It is associated with infection by various fungi; ordinarily the effects of individual species cannot be readily distinguished. Some fungi attack cruciferous and other plants only at the seedling stage and only under certain environmental conditions. In general, poor light, high mois-

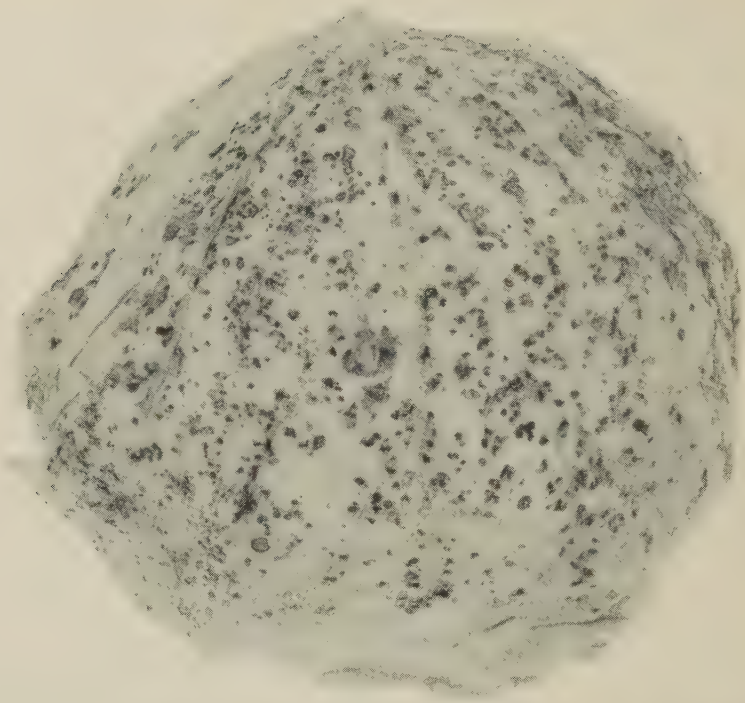

Figure 13.—Internal spots of cabbage head associated with infection by the mosaic viruses.

ture, and other factors that promote the rapid extension of seedlings above ground rather than slow extension and more rapid thickening bring on conditions conducive to damping-off. This effect has already been described in connection with the rhizoctonia disease (p. 20).

Damping-off may be caused by the watery soft rot fungus (p. 24), by the blackleg fungus (p. 18), and by the fungus which causes pythium head rot (p. 37) and its relatives.

Control of damping-off can be effected by the following practices:

(1) Use of only soil of good texture.
(2) Sterilization of soil if it is used repeatedly.
(3) Rotation of outdoor seedbeds.
(4) Avoidance of too thick sowing.
(5) Carefulness in watering.

LEAF SPOTS

Leaf spot phases occur in a number of diseases already described. Chief among these are black leaf spot (p. 25), blackleg (p. 18), ring spot (p. 27), white rust (p. 29), downy mildew (p. 28), powdery mildew (p. 28), cauliflower bacterial spot (p. 30), and rhizoctonia disease (p. 20).

Other leaf spots on crucifers are described in the following paragraphs.

Anthracnose.—Anthracnose is a common disease of turnip, Chinese cabbage, radish, and mustard in the South; it consists of relatively

small, brown-bordered spots with grayish centers often coalescing. When heavy infection occurs, it may cause considerable damage to turnip and Chinese cabbage. In moist weather the causal fungus (*Colletotrichum higginsianum* Sacc.) fruits abundantly in the center of the lesions and bears short-lived conidia, which are dispersed chiefly by raindrops.

White spot.—White spot is another disease common in the South on the hosts on which anthracnose occurs, but usually it is of little importance. It is distinguished by white, bleached spots. If these spots become very numerous they destroy the marketability of turnip greens. The causal fungus (*Cercosporella albomaculans* (Ell. and Ev.) Sacc.) produces conidia on the surface of the leaf lesions. A black, dendritic leaf spot of cabbage incited by the same species has been noted in the Pacific coast sections.

Other leaf spots.—A number of other fungi, particularly *Cercospora* spp. and *Ramularia* spp., cause leaf spots on the minor cruciferous crops, such as mustard, horseradish, bunching turnip, and water cress. These are generally of minor importance and need not be discussed in detail here.

NONPARASITIC MALADIES

LOW-POTASH INJURY

Crucifers as a whole thrive best on soils that are practically neutral in reaction. Extreme acidity such as prevails in some Atlantic seaboard soils results in abnormal growth, particularly if the soil solution is more acid than pH 5.

Cabbage is a heavy user of potash; when its supply falls below a certain level, disease symptoms appear. These are characterized by the yellowing of the foliage between the veins and particularly around the margins of the outer leaves, where the tissue eventually dies and becomes brittle and saprophytic fungi develop. As plants in this condition pass into the heading stage, the heads remain soft indefinitely; as a result a marketable crop fails to develop.

This condition can be readily prevented by testing the soil before planting; there should be 250 to 400 pounds of available potash per acre for a normal crop of cabbage. Even though effects of malnutrition fail to appear on the plants, a low-potash level results in cabbage of poor quality for sauerkraut manufacture.

MAGNESIUM-DEFICIENCY CHLOROSIS

In many soils in eastern United States a low level of available magnesium results in characteristic disease symptoms on cruciferous crops. Yellowish areas develop in tissue between the veins of the leaves, and a chlorotic condition not unlike mosaic results. As the disease advances, the mottled areas may change to light-colored desiccated spots. The chief distinction from low-potash injury is that the latter causes chiefly marginal yellowing and dying. The yield of affected plants may be greatly reduced. The condition can ordinarily be corrected by the use of fertilizer which is made slightly basic with dolomitic limestone and to which small amounts of soluble magnesium salts have been added.

BORON-DEFICIENCY INJURY

Boron is one of the minor nutritive elements essential for plant growth. In many soils, especially those which are alkaline in reaction, this element is deficient or it is in a form unavailable to plants. When such a deficiency prevails, turnip, rutabaga, cauliflower, and cabbage commonly show characteristic symptoms. In turnip and rutabaga dark-brown, water-soaked areas appear in the central flesh of the root either in small scattered spots or in large areas which may develop into a hollow center. In cauliflower the small leaves around the curd become deformed. The curd shows a brown discoloration which extends through the flesh, the core splits transversely and vertically, and the stem eventually becomes hollow. In cabbage there are sometimes mottling along the margins of the oldest leaves and cross hatching on the upper surface of the petiole and midrib. As a rule, however, no sign of the disease is seen until the head is cut, when water-soaked spots appear in the fleshy pith of the core and stem. These may be brown, and in extreme cases hollow cavities with dark-colored linings occur in the lower part of the core and upper part of the stem. When the crops mentioned are grown on soil which tends to produce plants showing symptoms of boron deficiency, 20 pounds of borax per acre should be applied broadcast and harrowed into the soil before the crops are planted.

WHIPTAIL OF CAULIFLOWER

Cauliflower plants sometimes form abnormally narrow, ruffled leaves with irregular margins, and in extreme cases enough dwarfing results to preclude heading. This disease, known as whiptail, is primarily a malnutritional disorder. It occurs chiefly along the Atlantic seaboard on highly acid soils. Recent work in New Zealand and Australia indicate that this disease is due to the lack of one of the trace elements, molybdenum. Control has been affected by broadcast application of ammonium molybdate (20 pounds or less per acre), and 1 ton of bone and blood manure per acre has reduced the disease 60 percent. Growers who have losses from this disease are advised to consult their county agents about the most recent control recommendations.

LOW-TEMPERATURE INJURIES

Many crucifers grow well in cool climates and in fact do their best in such an environment. In the Southern States, cabbage, cauliflower, turnip, and radish are favorite winter crops, since they harden well and withstand light frosts. Certain detrimental effects, however, can be recognized.

The bolting of cabbage without its coming to a mature head often occurs in the winter crop. This is brought about by protracted cool or frosty weather. Under such conditions cabbage goes through dormancy without heading. It is a purely environmental effect and cannot be attributed to poor seed stock, as is often done.

Multiple heading in the early northern cabbage crop from southern-grown cabbage plants sometimes causes appreciable losses. This is due to injury done to the main growing tip by frost when the plants are young. After transplanting, several side buds grow instead of the main growing point and several small unmarketable heads result.

Freezing injury is most common on the late-fall crop in the North. This subject is discussed further in the section on Transit and Storage Diseases (below).

FLOODING INJURY

The flooding of soil in cabbage fields is often the cause of the death of plants when the soil remains saturated for several days. Sudden, permanent wilt occurs, and the roots decay rapidly. This is not due to asphyxiation, as plants can be grown in liquid culture. It is more probably due to the abnormal anaerobic fermentation set up by the soil flora, which liberates substances in the soil solution that are toxic to the plants.

LIGHTNING INJURY

When lightning strikes the earth in cabbage fields, plants soon wilt in roughly circular areas of various sizes. Within a few days most of the plants are dead. Such lightning spots are usually not observed until some weeks after the occurrence, and there is thus commonly some question as to the cause. Certain characteristics help to distinguish it.

Around the margin of the area are to be found plants which are weakened or slowed up in growth. As these are pulled, it is usually found that the lightning scar is at the soil line and is limited to the side facing the center of the area. Sometimes this injury is slight and is rendered conspicuous by being callused over. Greater injury leads to a side stem growing out just below this point or to adventitious roots forming just above it. The electric charge apparently passes directly to the pith of the stem, in which it is conducted more readily. The lightning injures the pith most readily also; some time after the injury the pith is hollow and dark-colored, and within it an abnormal development of fibrous roots occurs. The peculiar earmarks of lightning injury are very useful in diagnosing it several weeks later.

INTUMESCENCES

On leaves and stems of cabbage, cauliflower, and other cruciferous plants in the field often occur wartlike projections the size of a pinhead or larger. They may be scattered in large numbers over both surfaces of the leaf. These are the result of injury to the tissue brought about by the blowing of soil particles against the leaves. As a result of the wound, the tissues respond by building up callus, which takes this form. The protuberances are of no great importance, but owing to their conspicuous nature they often attract attention.

TRANSIT AND STORAGE DISEASES [3]

Various diseases that cause direct loss or necessitate heavy trimming of cabbage in storage are described briefly so that they can be recognized and avoided.

[3] Adapted by D. H. Rose, senior physiologist, Division of Fruit and Vegetable Crops and Diseases, from Miscellaneous Publication No. 292, Market Diseases of Fruits and Vegetables: Crucifers and Cucurbits. That publication may be consulted in libraries.

Heavy losses of cabbage occur annually as a result of freezing, both in the field (p. 34) and after harvest. Cabbage tissue has one of the highest freezing points (31° F.) found among vegetables. Sometimes frozen cabbage will thaw out without injury and sometimes it will not. In the former case the tissues are merely frozen, while in the latter they are frozen to death. However, there is no way of telling by examination of a frozen head of cabbage or of other vegetables which act similarly whether they will show injury and breakdown when they thaw out. Immediately after they are thawed, the frozen areas look water-soaked, because of suffusion with water liberated in the intercellular spaces by the thawing ice. If the cells are still alive, some of the water will go back into them; the only effect on the tissue is a slight wilting or shriveling due to the excessive loss of water by transpiration and evaporation. Tissues responding in this way become flabby, pithy, or spongy and tough and lose their characteristic flavor. Some of them can withstand the freezing process several times before the effect becomes pronounced; others show it immediately. If the cells are not alive, the water does not reenter them; it may be lost rapidly into the air, with attendant drying out of the tissues; or it may remain and the tissues become a leaking, disorganized mass, which is attacked by saprophytic fungi and bacteria.

Whether ice formation in the tissues is attended by permanent injury and death seems to depend upon the degree to which the temperature falls, the rate at which it falls, the duration of the critical temperature, and the condition of the plant tissues themselves.

The presence of ice in cabbage tissues renders them rigid or brittle. Frozen leafy tissues and even such storage tissues as in turnip and rutabaga lose their natural luster and take on a glassy appearance. Immediately upon thawing, they become water-soaked. The leafy green tissues in the water-soaked area also have a dirty- or muddy-green color. In colorless or fleshy parts there is at first no discoloration. Later the more sensitive tissues, especially the water-conducting tissues, may become yellowish brown and finally black.

In cabbage there is no such discoloration save possibly in parts of the stem. If the tissues have not been killed, they soon lose the water-soaked appearance and look much as they did before, except that they may be more flabby. If the tissues are killed, discolorations usually develop; these discolorations vary with the different kinds of vegetables and tissues. The epidermis of tender, leafy tissues, such as in cabbage, Italian broccoli, kale, and mustard, is often loosened in spots, especially along the petioles, midrib, and smaller veins; it appears blistered and can be removed easily. Fleshy tissues such as in turnip, radish, rutabaga, and horseradish often show no discolorations except in the water-conducting tissues; these become yellow, brown, or black.

In cabbage the outer leaves seem to be more resistant to killing by freezing than the inner leaves and the stem. Generally they thaw out without injury. After prolonged exposure to freezing temperatures, the inner tissues, especially the pith of the stem, usually are killed; soon they become affected with bacterial soft rot.

In dry air the killed tissues may dry out. Leafy tissues usually become brittle and parchmentlike; more fleshy ones become spongy

and pithy or hard and stony. In moist air various rots develop, depending upon the external conditions. Thin, leafy tissues usually are affected with bacterial soft rot, alternaria rot (black leaf spot, p. 25), or gray mold rot. More fleshy ones are attacked by bacterial soft rot, rhizopus rot, or other rots.

Control is obtained by preventing exposure of the products to critical cold temperatures for a long enough period to cause their death.

BACTERIAL SOFT ROT

As stated previously (p. 23), the diseases grouped as bacterial soft rot are caused by bacteria of the *Erwinia carotovora* group. Soft rot probably causes more loss on the market than any other disease of cabbage and related crops. The reason is that practically all invasion of tissue by soft rot organisms is through wounds, the lesions of other diseases, or tissues weakened by mechanical agencies, freezing, asphyxiation, or aging. These organisms will attack only injured or dead tissues, and such tissues only when they are wet. Breaks in the tissues or moistened surfaces provide the water and food the organisms need to get started and to carry on growth and reproduction.

The pith of stems or roots is very often affected; in cabbage the resultant condition is often referred to as "stump rot." Stump rot usually follows infection during cutting or after freezing. Unless care is taken in cutting to avoid heads affected with bacterial soft rot, it is easy to carry bacteria on the knife from diseased heads to the freshly cut stems; when moist these stems provide ideal starting places for decay. In turnip and other root crops the lesions usually occur in the pith, starting at the crown of the plant. In cabbage the lesions usually are on the surface or in the pith, following bruises or wounds. If the lesions are on the surface, the outer decayed tissues can be removed and the progress of the disease arrested by drying the freshly exposed surface. If the stem is invaded or the disease penetrates deep into the head following black rot (p. 15), the entire head is worthless.

In transit and storage soft rot may be spread by contact or by the oozing or dripping from the decayed tissues. There probably is much less actual spread of this decay in transit than of many fungus rots because bacteria do not form mycelia, or fungus threads.

The soft rot organisms are particularly sensitive to drying and to direct sunlight. Wet, warm weather favors the rot.

PYTHIUM HEAD ROT

The pythium head rot fungus travels rapidly along the midrib, which is reduced to a soft, pulpy consistency but is held together by outer layers of tissue. Offensive odor is not characteristic, and the mycelium in the decaying tissue has practically no cross walls. The causal fungus (*Pythium debaryanum* Hesse) and its close relatives are common causes of soft decays of storage organs of fruits and vegetables. They also cause rootlet decay and damping-off of many plants (p. 31).

RHIZOPUS SOFT ROT

Crucifers are often subject to infection by a fungus known as *Rhizopus*. This fungus is ever present in the air and soil, and con-

sequently there is always more or less danger of infection if conditions are favorable. This disease is of little or no consequence in the field or on leafy crops such as mustard and kale; but on the more fleshy vegetables such as cabbage, cauliflower, turnip, and rutabaga consequent decay developing during transit and marketing sometimes causes considerable loss. The chief predisposing factors are wounds and high temperature. *Rhizopus* does not affect cabbage, cauliflower, or root crops in cold storage (32° F.).

In succulent tissues the decay is light brown, soft, and watery. In roots the rot is moderately soft and moist, but it lacks the characteristic disagreeable odor of the bacterial soft rot (p. 22) that sometimes presents a similar appearance. Usually in cabbage, cauliflower, brussels sprouts, and turnip, the coarse, stringy fungus threads bearing white and black fruiting bodies make the diagnosis of this disease fairly easy.

GRAY MOLD ROT

In cabbage, cauliflower, and turnip, as in most other vegetables, gray mold rot, caused by a fungus known as *Botrytis cinerea* Fr., occurs most commonly in aging tissues. Consequently it is of most importance in storage. There it is sometimes the most important single factor of loss, since the causal organism can grow at cold-storage temperature. The rot is found even in freshly harvested stock if conditions are especially favorable for the fungus. Chief among these is high humidity. If this is associated with moderate temperature, the fungus attacks even the outer, aging leaves of growing plants. Water-soaked, grayish-green areas are produced, and usually a gray mold is present on the surface of affected tissues. In the more advanced stages of decay the grayish-brown vegetative threads and spore clusters of the fungus are characteristic.

BLACK LEAF SPECK

Black leaf speck is characterized by small, sharply sunken, brown or black specks occurring anywhere on the leaves of cabbage, cauliflower, and Chinese cabbage, from all sections. At times these specks are found in great abundance, especially on the leaf blades. They may occur in a few of the outer head leaves only or in leaves throughout the head. Frequently it is difficult to distinguish them from the early stages of black leaf spot (p. 25), which occurs in California cabbage, and from ring spot (p. 27) as it appears in Oregon cauliflower. The spots render these products unsightly, thus affecting their marketability. They also tend to lower their resistance to storage rots.

Very little is known about the factors that bring about black leaf speck, save that it is not caused by organisms. It occurs commonly in transit and storage; for this reason it might be classed as a break-down associated with low temperature. It also occurs sometimes in the field, where it has been found, in some instances at least, to have been associated definitely with a decided drop in temperature.

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